In Situ and Satellite Sea Surface Temperature (SST) Analyses

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1. PROJECT SUMMARY

The purpose of this project is to focus on improvements to the climate-scale sea surface temperature (SST) analyses produced at NOAA. The major effort has been the development of a new daily optimum interpolation analysis, which was designed use multiple satellite data sets as well as in situ data. There are two products. One product uses infrared satellite data from the Advanced Very High Resolution Radiometer (AVHRR). The second product uses AVHRR and microwave satellite data from the Advanced Microwave Scanning Radiometer (AMSR) on the NASA Earth Observing System. The AVHRR-only product now begins in November 1981 and the AMSR+AVHRR product begins in June 2002 when the microwave satellite data became available. Both products include a large-scale adjustment of satellite biases with respect to the in situ (ship and buoy) data. Two products are needed because there is an increase in signal variance when microwave satellite data became available due to its near all-weather coverage.

Additional efforts have been carried out to improve the Extended Reconstruction SST analysis. This analysis presently uses in situ data and begins in 1854. The reconstructions were produced from a low frequency (or decadal-scale component) and from a residual high-frequency component. The high frequency analysis was performed by fitting the observed high frequency anomalies to a set of large-scale spatial-covariance modes. A new version is produced which improves the damping in the late 19th century. However, satellite data which was originally added beginning in 1985 has now been removed because of residual biases which impacted the trend and yearly rankings.

One of the important goals of the Sustained Ocean Observing System for Climate is to improve the SST accuracy over the global ocean. Because of the high coverage of satellite data, in situ data used in the analysis tends to be overwhelmed by satellite data. Thus, the most important role of the in situ data in the analysis is to correct large-scale satellite biases. Simulations with different buoy densities showed the need for at least two buoys on a 10° spatial grid. This will ensure that satellite biases do not exceed 0.5^oC. Using this criterion, regions were identified where additional buoys are needed, and a metric was designed to measure the adequacy of the present observing system. Improved bias correction methods now being developed may reduce the needed sampling.

Richard W. Reynolds serves on the Ocean Observation Panel of Climate (OOPC) and the Global Ocean Data and the Assimilation Experiment High Resolution Surface Temperature Pilot Project (GHRSST-PP) Science Team. Members of both groups consist of well-known national and international scientists. All work presented here follows the Global Climate Observing System (GCOS) Ten Climate Monitoring Principles.

2. FY 2006 PROGRESS

2.1. The High-Resolution Daily SST Analyses

During FY2006, two new daily 1/4° SST analyses were developed: the AVHRR-only daily optimum interpolation (OI) from January 1985 to present and the AMSR+AVHRR daily OI from June 2002 to present. During FY2007 a Journal of Climate paper was written to describe the product (see Reynolds et al., 2007). Both analyses use in situ data and use a satellite bias correction. In FY2007 a web server was developed: http://www.ncdc.noaa.gov/oa/climate/research/sst/oi-daily.php. The server allows users to get information on how the analyses were generated and to download the data in NetCDF or IEEE binary. The user interface also allows users to generate plots as needed and to generate digital output files in different formats including ASCII.

In FY2008, the daily analysis was upgraded to version 2. These changes primarily consist of additional temporal smoothing. In addition, a preliminary Pathfinder dataset as been prepared using NOAA-7 following Kilpatrick et al. (2001). Using these data, the AVHRR-only daily OI was extended backward in time to November 1, 1981. Complete details of the improvements are given in Appendix A – What's new in version 2. Version 2 is now being run in real-time.

2.2. The Historic ERSST Analysis

In FY2007 changes were made to NOAA's Historical Merged Land-Ocean Surface Temperature Analysis. This version is version 3 and is documented in Smith et al. (2008). The analysis is derived from two independent analyses, a sea surface temperature (SST) analysis, the Extended Reconstruction of SST version 2 (ERSST), and a land surface temperature analysis using the global historical climatology network temperature database.

As explained in the preprint, there are 2 major changes of version 3 over version 2. First, the tuning procedures were improved using simulated data. The result of the change is that data have a stronger influence on the analysis prior to 1930. The second change was the addition of satellite data to the SST analysis beginning in 1985. Although, the satellite data were corrected with respect to the in situ data as described in preprint, there was a residual cold bias that remained as shown in Figure 4 Smith et al. (2008). The bias was strongest in the middle and high latitude Southern Hemisphere were in situ data are sparse. The residual bias led to a modest decrease in the global warming trend and modified global annual temperature rankings. To avoid this problem, the satellite SST data were removed from version 3. To distinguish this change, the latest version is termed version 3b; the version described in the preprint is version 3a.

Version 3b also has one additional change. The most recent ICOADS in situ data were used through 2006 supplemented by GTS after 2006. In addition, the same quality control procedures have been used through out the analysis period. This change was very modest and impacts the global monthly mean values by less than 0.02°C.

There is also a one additional minor change in both version 3a and 3b and described in the preprint. The sea ice data are now processed directly. This change allows the analysis to be made in a more timely fashion. Analyses for the previous month are now available on the third day of the current month.

2.3. Design of an In Situ SST Network to Improve the SST Analysis

During the preceding years, an in situ network to correct "potential satellite bias errors" was determined using simulated biased satellite retrievals and simulated unbiased buoy data. The maximum "potential satellite bias error" was selected to be 2^oC as a worse case. Thus, the "potential satellite bias error" would be 2^oC if there were no in situ data to correct the bias. The data density of the present in situ network was evaluated to determine where more buoys are needed. These buoys could be either moored or drifting. However, because of the high cost of moored buoys, they will be assumed to be drifters. To reduce the potential satellite bias to below 0.5^oC, a buoy density of about 2 buoys/10° grid is required. The present in situ SST observing system was evaluated to define an equivalent buoy density allowing ships to be used along with buoys according to their random errors. These figures are operationally produced seasonally and are used to guide surface drifting buoy deployments. Updated documentation is available in a recent paper by Zhang, et al. (2008).

3. REFERENCES

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Smith, T.M., R. W. Reynolds, T. C. Peterson, and J. Lawrimore, 2008: Improvements to NOAA's historical merged land-ocean surface temperature analysis (1880-2006). *J. Climate,* **21***,* 2283-2296.

Zhang H. M., Reynolds, R.W., Lumpkin, R., Molinari, R., Arzayus, K., Johnson, M., and Smith T.M., 2008: An Integrated Global Ocean Observing System for Sea Surface Temperature Using Satellites and In situ Data: Research-to-Operations. *Bull. Amer. Meteor. Soc.*, **89,** in press.
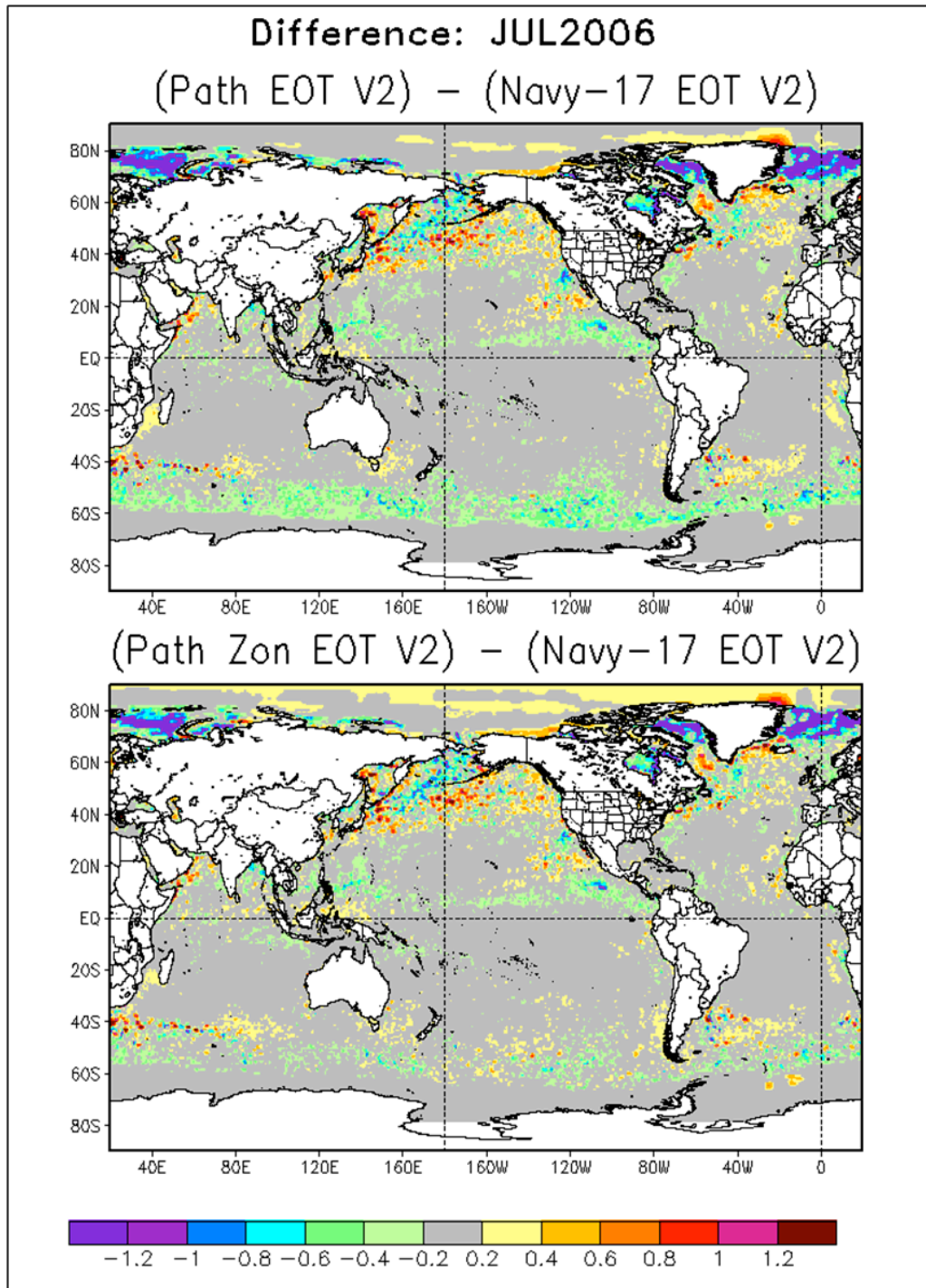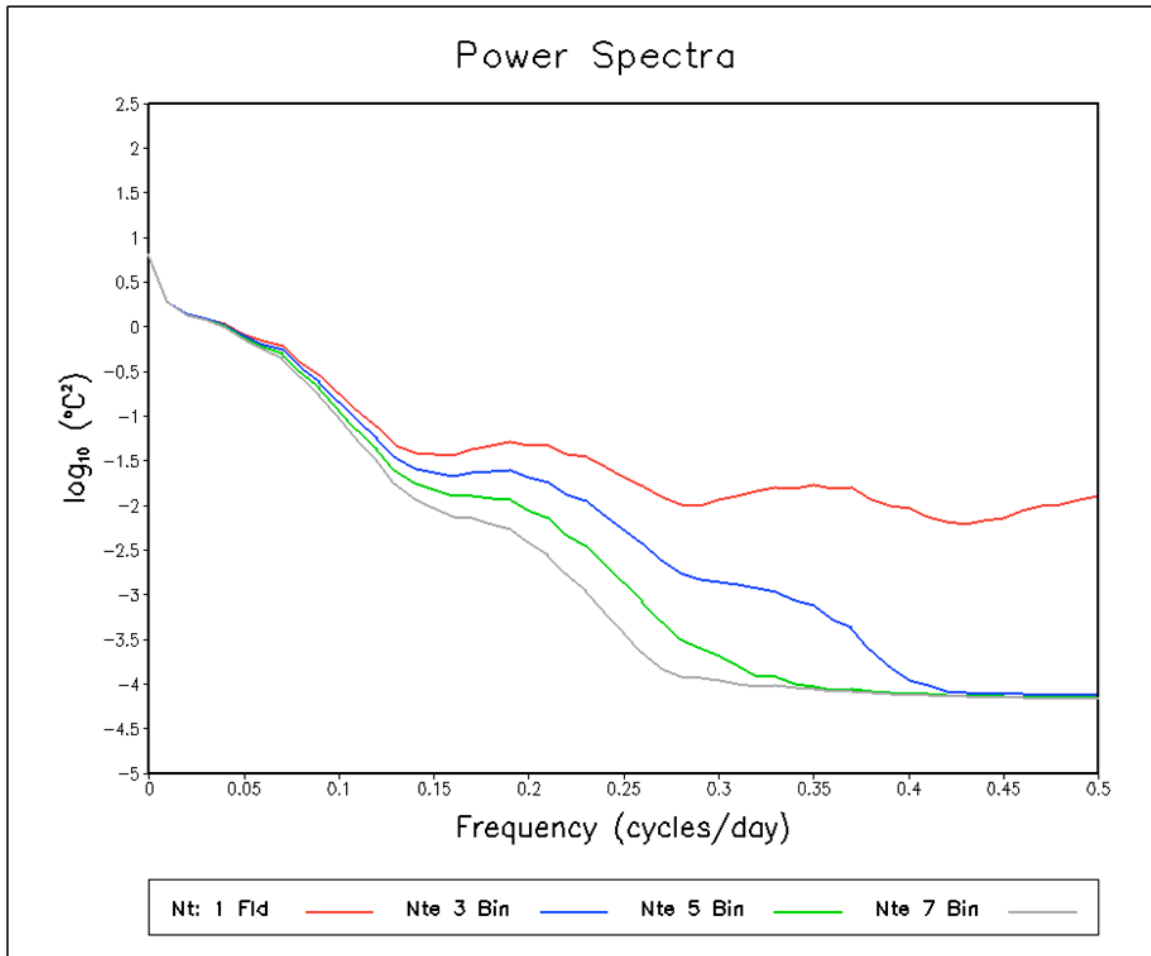
4. FIGURES
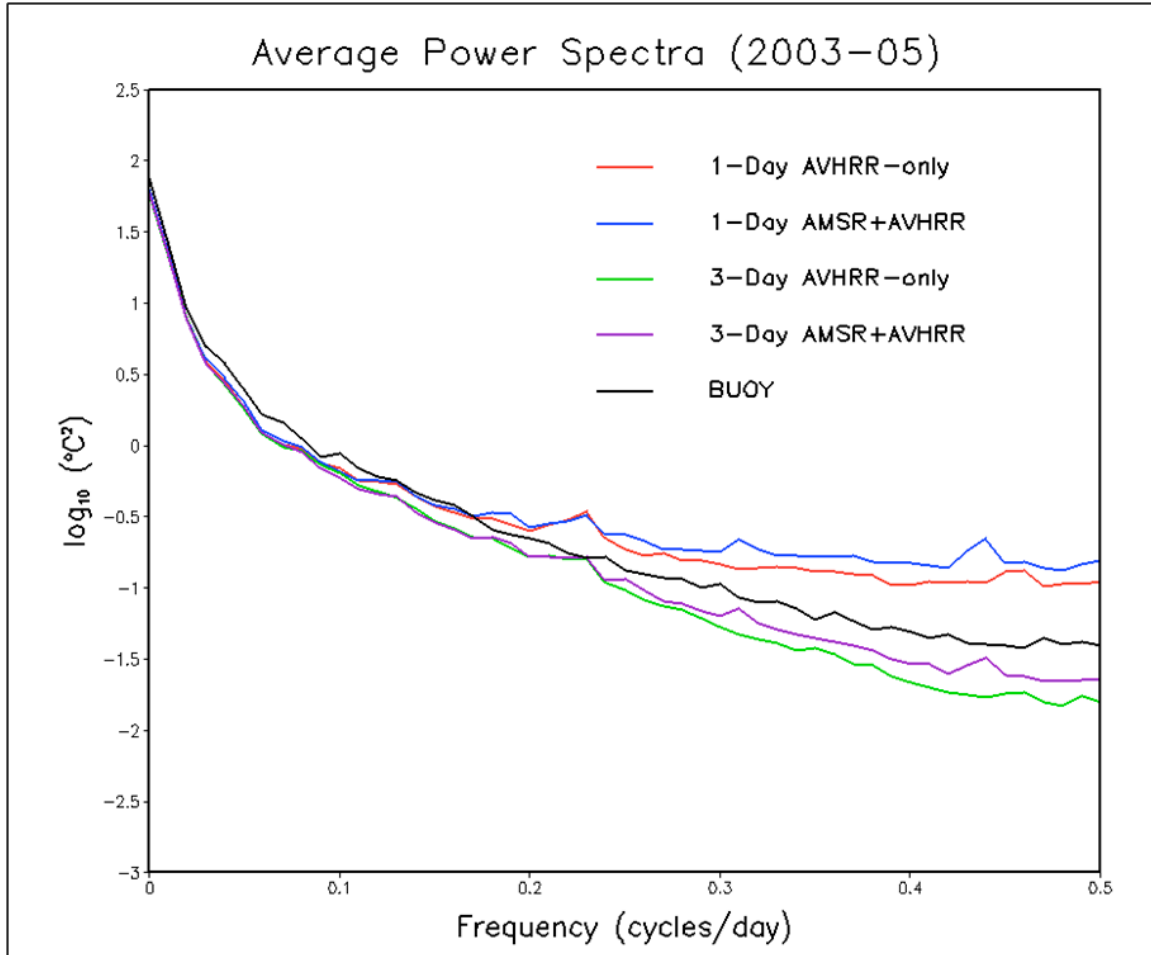
Figure 1. Globally averaged daily spectra for 2003-05 computed at 43 moored buoy locations and averaged. 'AVHRR-only' and 'AMSR+AVHRR' indicate daily OI spectra using either 1-day or 3-days of data. 'Buoy' indicates spectra using daily buoy data.
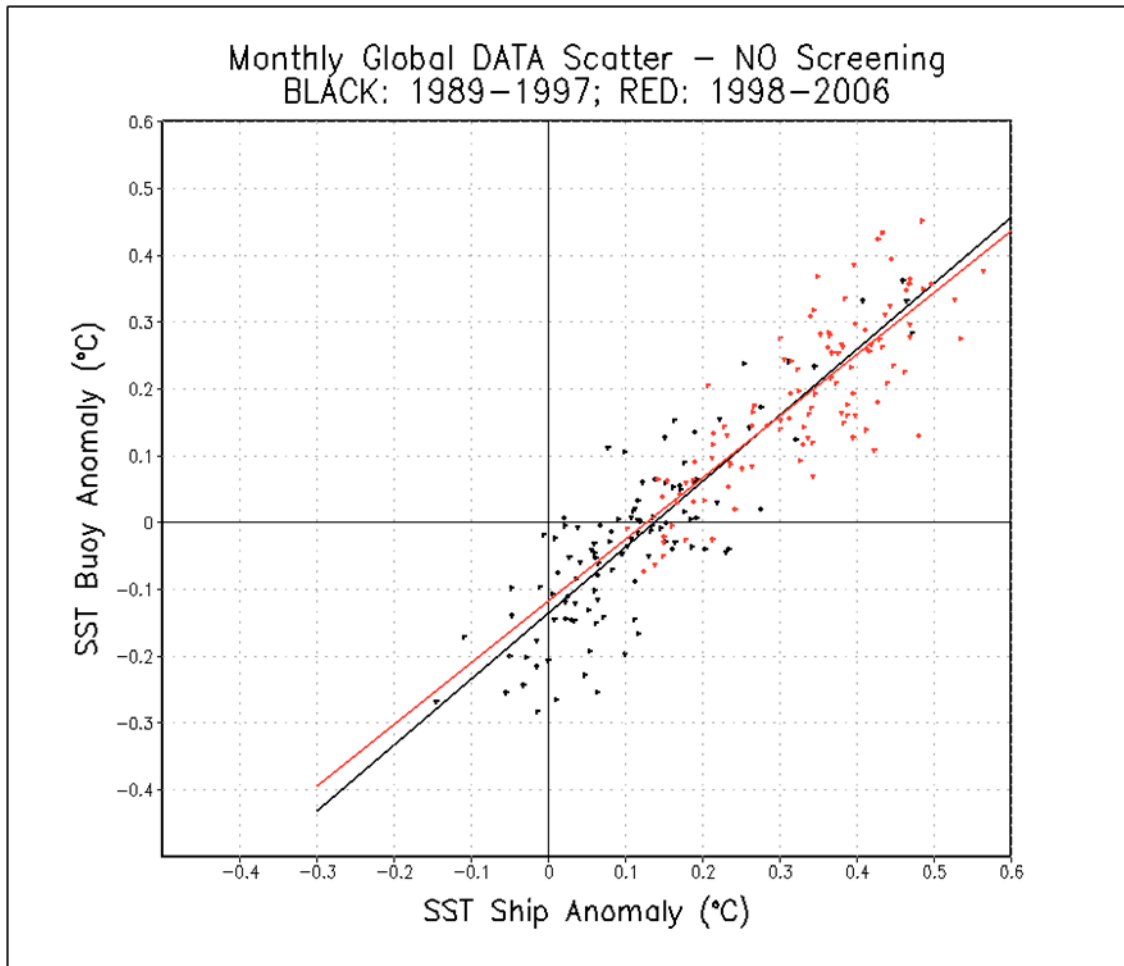
Figure 2. Scatter plot of global collocated average monthly ship vs. buoy anomaly for January 1989 - December 2006. The first 9-years are shown in the black and the second 9-years in red. Least squares linear fits for the two periods are also shown.

Figure 3. Average July 2006 difference between the daily AVHRR-only OI using Pathfinder NOAA-17 data and Operational Navy NOAA-17 data. All versions use bias corrected satellite data. In the top panel the Pathfinder daily OI uses no preliminary zonal bias correction; in the bottom panel the Pathfinder daily OI uses a preliminary zonal bias correction.
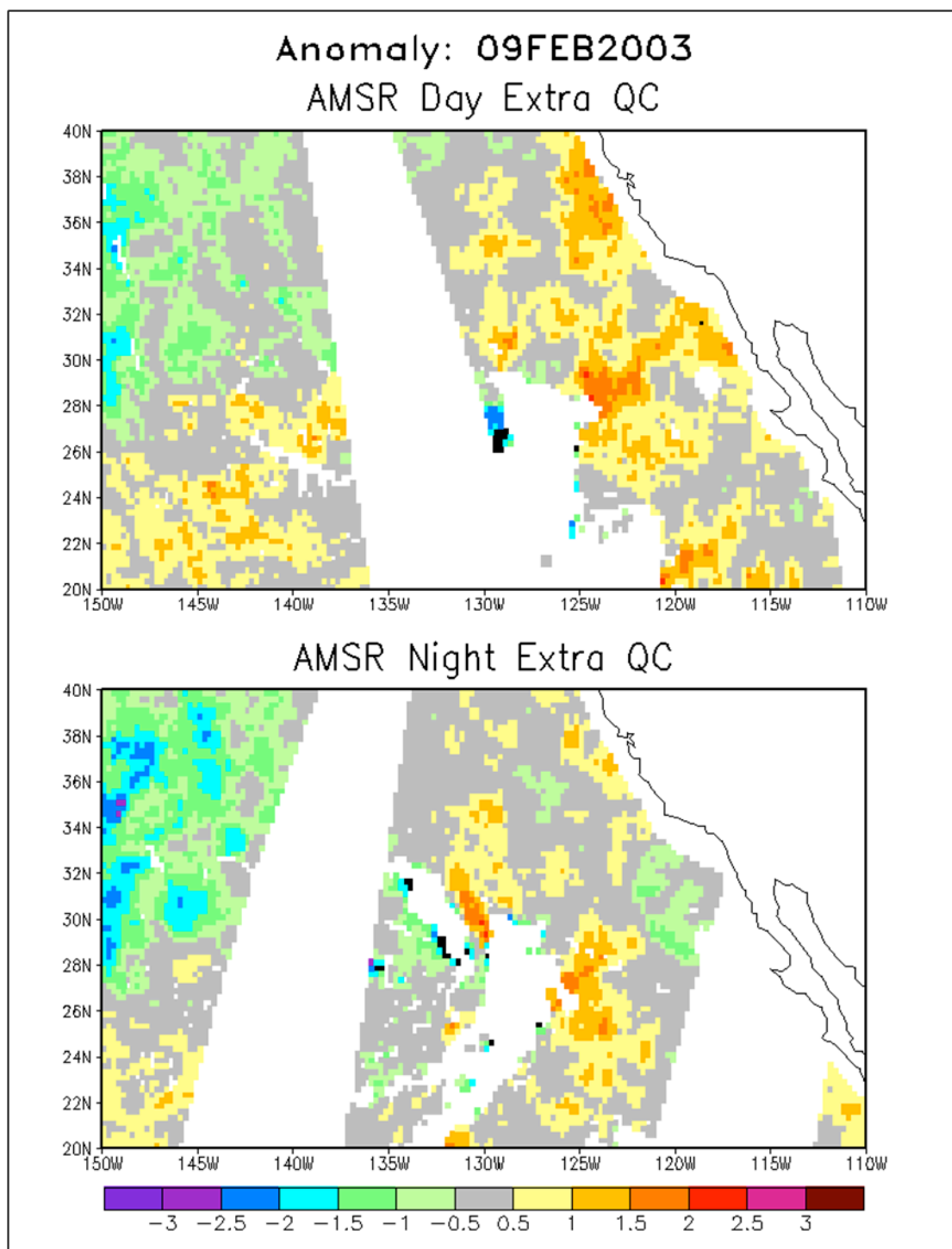
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Figure 4. Spatially averaged nighttime AVHRR bias correction spectra for 2000-2005. Binomial 3-point, 5-point and 7-point temporal smoothing are shown; an unsmoothed version is labeled 'Nt 1 Fld'.
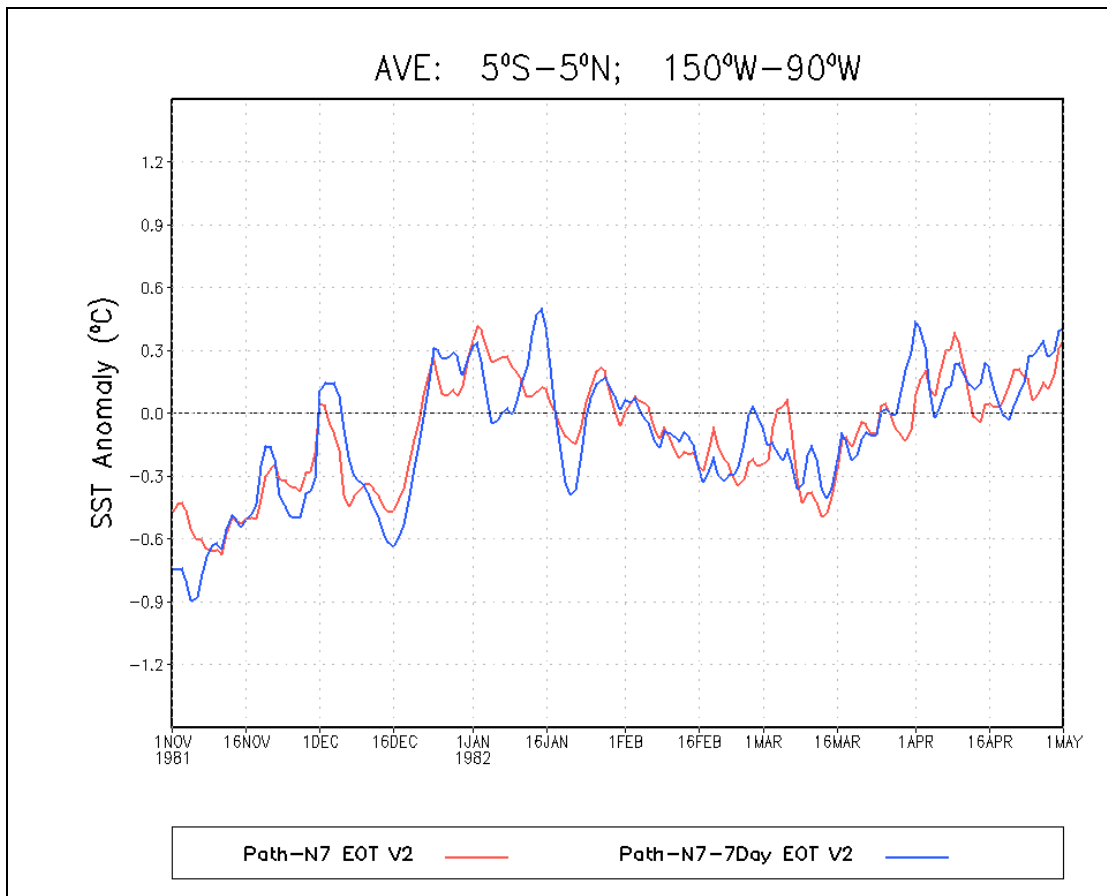
Figure 5. Daily OI Nino-3 anomalies using EOT bias correction with 15 and 7 days of data. 'N-7' indicates that NOAA-7 satellite SST data are used.

Figure 6. AMSR extra quality controlled SST data anomalies for 9 February 2003. The black regions show where data have been rejected by the extra quality control.